A REPORT ON THE WATER QUALITY OF SELECTED LAKES IN KETTLE LAKES PROVINCIAL PARK

1975

Ministry
of the
Environment
Ontario

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THE WATER QUALITY OF SELECTED LAKES
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CONTENTS

SUMMARY AND CONCLUSIONS

Bullfrog, Island and Slab Lakes are soft water lakes, as indicated by relatively low conductivity, alkalinity and generally low concentrations of the major ions. Slab Lake appeared significantly more dilute than Bullfrog and Island Lakes.

Concentrations of nitrogen in the study lakes were generally low, while relatively high concentrations of phosphorus were found in Slab and Bullfrog Lakes. Recorded phosphorus concentrations in these lakes in some cases exceeded the level considered capable of inducing nuisance growths of algae. Of further concern are the low concentrations of dissolved oxygen recorded in Slab and Bullfrog Lakes. Concentrations below the level required for fish survival were found in these lakes.

Due to limited inflow and outflow, the study lakes have a very slow flushing rate. The low degree of flushing in these systems makes them very vulnerable to inputs since materials added have a long residence time.

Based on the results of chlorophyll *a* - Secchi disc monitoring, Island and Slab Lakes appear to be oligotrophic while Bullfrog Lake appears mesotrophic.

RECOMMENDATION

It is recommended that the study be continued as planned to determine if any changes in water quality related to user activity within the park are occurring with time.

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE:

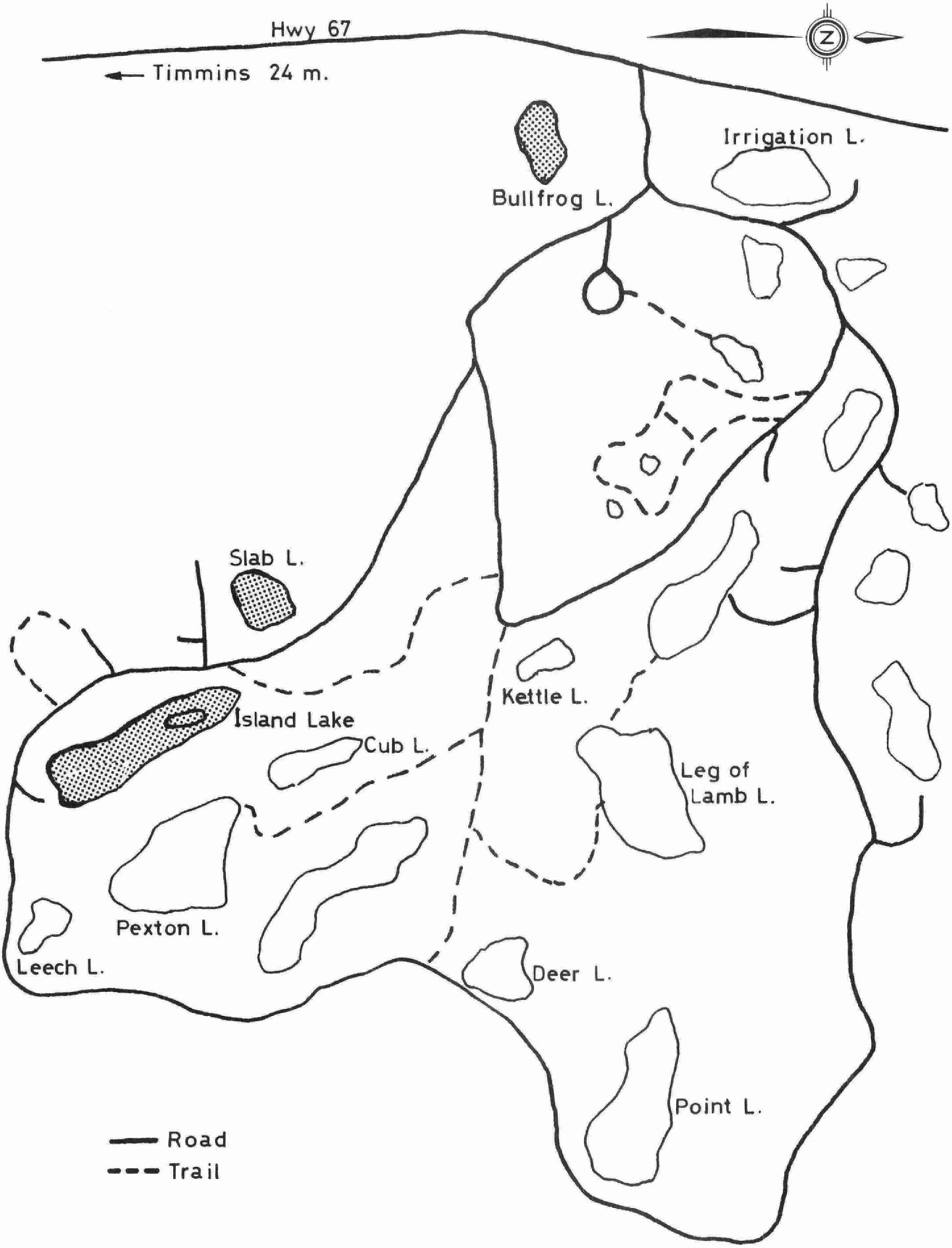
During January 1973, concern over alleged deterioration of water quality in Island Lake, within Kettle Lakes Provincial Park, was expressed via the Environmental Law Association. Concern was centered on possible nutrient induced eutrophication as indicated by the occurrance of "water blooms" of filamentous green algae (*Spyrogyra* sp.) during the summers of 1971 and 1972.

In response to this concern, a Secchi disc - chlorophyll *a* monitoring programme was initiated on Island, Slab and Bullfrog lakes (see Figure 1.1.1). Weekly sample collections by Ministry of Natural Resources staff commenced in the spring of 1973 and continued throughout the summer. In addition, an investigation of other water quality parameters was carried out in midsummer by Ministry of the Environment personnel to supplement the Secchi disc - chlorophyll *a* data.

The maximum value of a Secchi disc - chlorophyll *a* monitoring programme is only realized when sampling is continued over a number of years since a major function of the initial years' data is to provide baseline information from which future changes may be determined. Therefore, it was intended that the sampling programme in Kettle Lakes Park be a continuing effort and in this regard, additional sampling was carried out during the summer of 1974. It is hoped that chlorophyll *a* Secchi disc monitoring will continue during the summer of 1975.

The following report presents the results obtained during 1973 and 1974 and discusses them, particularly in terms of trophic status.

FIGURE 1.1.1. — MAP OF KETTLE LAKES PROVINCIAL PARK SHOWING THE STUDY LAKES



1.2 DESCRIPTION OF THE STUDY AREA:

Kettle Lakes Provincial Park is situated 24 miles east of Timmins on Highway 67. The park is located on an area of fertile soils characterized by hummocky hills and Kettle Lakes (a recessional morraine in geological terms).

The local topography is typical of deposition from a recessional morraine. Slight oscillations of an ice front as it recedes result in an irregular belt of knolls and basins, usually described as knob and basin topography. The hummocky hills and Kettle Lakes in this area are similar geomorphic features associated with the melt of stranded ice blocks.

A summary of morphometric data for the study lakes is provided in Table 1.2.1.

TABLE 1.2.1

MORPHOLOGICAL CHARACTERISTICS OF THE STUDY LAKES

LAKE	AREA		MAXIMUM DEPTH		MEAN DEPTH	
	Hectares	Acres	Metres	Feet	Metres	Feet
Bullfrog	2.3	5.6	5.2	17	2.5	8.1
Island	9.3	23.1	10.9	36	3.1	10.3
Slab	2.7	6.8	11.3	37	5.5	18.0

Note: Morphometric data provided by Ministry of Natural Resources.

Kettle Lakes Provincial Park is classed as a recreation park, offering services and facilities for camping and daytime use. Slab Lake receives heavy day use while tent and trailer site developments are located at Bullfrog and Island lakes (50 and 117 campsites respectively).

During 1973 and 1974, the park received 76,844 and 58,175 visitors respectively.

2.0 METHODS

2.1 PHYSICO - CHEMICAL:

On August 9, 1973, duplicate samples were collected with a Van Dorn sampler from one m below surface and one m above bottom at each lake. Samples were retained in a portable cooler during transportation to the field laboratory where pH and conductivity measurements were made. Subsequently, samples were shipped to the Ministry of the Environment laboratory in Toronto for analyses including:

calcium	nitrogen
magnesium	phosphorus
sodium	iron
potassium	silica

Additionally, temperature and dissolved oxygen depth profiles were determined in the field at each location.

On August 22nd, 1974, a similar survey was carried out however, analyses were limited to nitrogen, phosphorus, iron and conductivity and only spot measurements of dissolved oxygen were taken.

2.2 CHLOROPHYLL A - SECCHI DISC:

Secchi disc readings and samples for chlorophyll a analyses were taken throughout the summer of 1973.

Secchi disc readings are taken by lowering the disc (20 cm in diameter with alternating black and white quadrants) to the depth at which it just disappears. This depth is recorded and the disc is raised to the point at which it reappears and that depth is recorded. The point halfway between these two readings is the Secchi disc transparency depth.

Chlorophyll a samples were collected as composites through the euphotic zone (zone of significant light penetration - taken as twice the Secchi disc depth). A composite sample is collected by lowering a one l glass bottle in a weighted sampler to a depth equal to twice the Secchi disc reading and then retrieving it at such a rate to allow complete filling as it reaches surface - the object being to collect water equally from all portions of the measured sampling column. Figures 2.2.1 and 2.2.2 are schematic representations of the methodology of composite sampling and the composite sampler respectively.

Samples for chlorophyll a analyses were immediately stabilized with

FIGURE 2.2.1

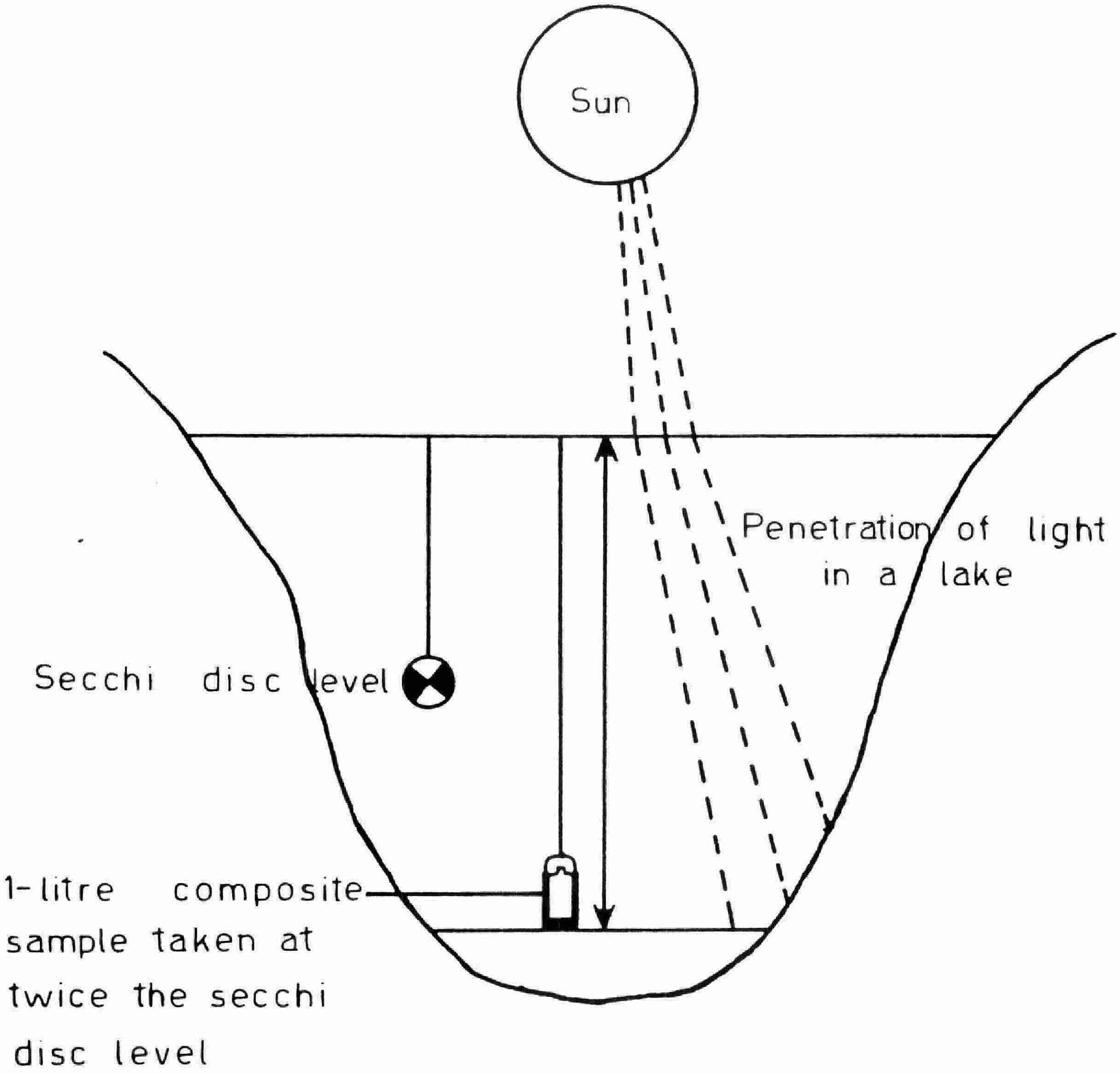
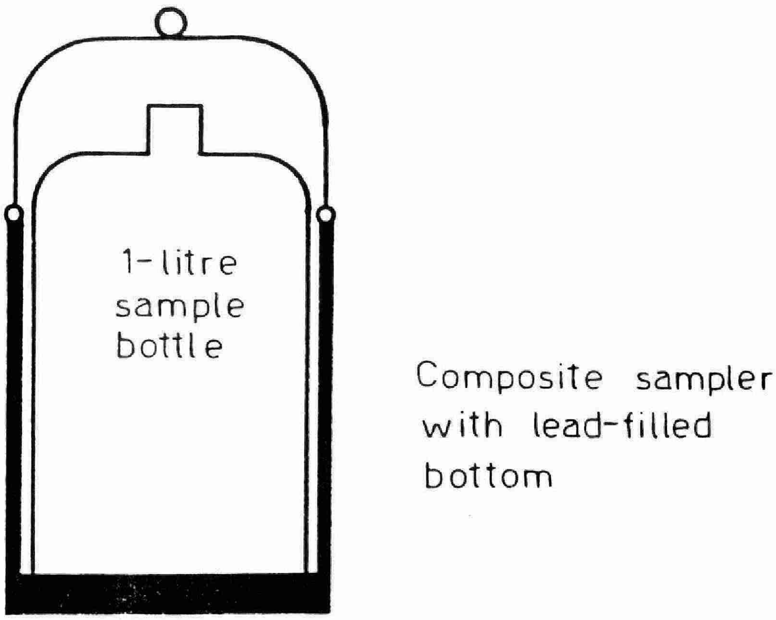


FIGURE 2.2.2



sufficient magnesium carbonate solution (2% weight to volume ratio) to elevate the pH and retard the breakdown of chlorophyll a during transportation. Samples were shipped to Toronto and analysed in the Ministry of the Environment laboratory within 48 hours of the time of receipt.

3.0 RESULTS AND INTERPRETATION

3.1 TEMPERATURE AND DISSOLVED OXYGEN:

The results of temperature and dissolved oxygen measurements are provided in Table 3.1.1. Depth profiles based on the data recorded in Table 3.1.1 are depicted in Figures3.1.1 and 3.1.2 for temperature and dissolved oxygen respectively.

The distribution of temperature with depth is extremely important in a lake since a well established thermocline (zone of rapid temperature decrease with depth) acts as a barrier to vertical diffusion - effectively isolating the surface waters (epilimnion) from the bottom waters (hypolimnion).

As shown in Figure 3.1.1, Bullfrog and Island lakes did not show meaningful thermal stratification on either sampling date with only a slight temperature decrease evident between the surface and bottom waters. The relatively uniform temperature profiles observed in these lakes are no doubt a reflection of their shallow depth, which permits thorough wind mixing. Slab Lake, significantly deeper than the other study lakes, exhibited a thermocline beginning at 5 m in 1973 and 6 m in 1974. On both sampling dates, the zone of greatest temperature decrease extended to 9 m; however,a noticeable temperature reduction continued from 9 m to the lake bottom.

The concentration of dissolved oxygen in a lake is extremely important since fish and other aquatic life forms require oxygen for respiration.

In 1973, Bullfrog Lake exhibited a dissolved oxygen profile which may be termed clinograde based on a significant oxygen reduction with increasing depth (see Figure 3.1.2). Distributions of this type are generally considered typical of eutrophic lakes. The virtual absence of dissolved oxygen in the bottom waters of Bullfrog Lake in 1973 (.2 mg l^{-1}) is of major concern since it precludes the use of the deeper areas of the lake by fish. In 1974, the bottom water dissolved oxygen concentration was significantly higher (4 mg l^{-1}) than in 1973;however, values of this magnitude are still critical to fish survival (Ministry of the Environment, 1972).

Island Lake exhibited a very irregular dissolved oxygen profile with abundant dissolved oxygen present throughout the water column. Concentrations tended to be highest in the mid-waters and bottom waters.

The dissolved oxygen profile of Slab Lake may be classed as clinograde based on a reduction with depth; however, the most striking feature of the

TABLE 3.1.1

RESULTS OF TEMPERATURE AND DISSOLVED OXYGEN MEASUREMENTS, AUGUST 9, 1973 AND AUGUST 22, 1974

Lake	Depth (m.)	Temperature (^{o}C)		Dissolved Oxygen (mg l^{-1})		Dissolved Oxygen (% Sat.)	
		1973	1974	1973	1974	1973	1974
Bullfrog	1	21.5	22.0	10.1	8	117	94
	3	20.8	21.6	9.8		112	
	4	19.0	21.2	8.3		93	
	5	18.0	19.9	.2	4	3	4545
Island	1	23.5	22.0	12.3	5	147	59
	2	23.0	22.0	14.0		165	
	3	23.0	22.0	13.0		155	
	4	22.7	21.5	13.2		157	
	5	22.5	21.0	13.0		154	
	6	22.5	19.0	13.6	10	160	111
Slab	1	23.3	21.7	11.2	8	135	93
	2	21.8	21.7	11.6		136	
	5	21.8	21.1	11.2		130	
	6	16.8	20.5	15.4		152	
	7	14.8	16.8	15.8		160	
	8	12.4	13.0	15.2		145	
	9	10.1	11.0	14.6		133	
	10	9.0	9.8	8.6		77	
	11	8.3	8.8	2.0	6	18	67

FIGURE 3.1.1.

TEMPERATURE - DEPTH PROFILES

1973 - 1974

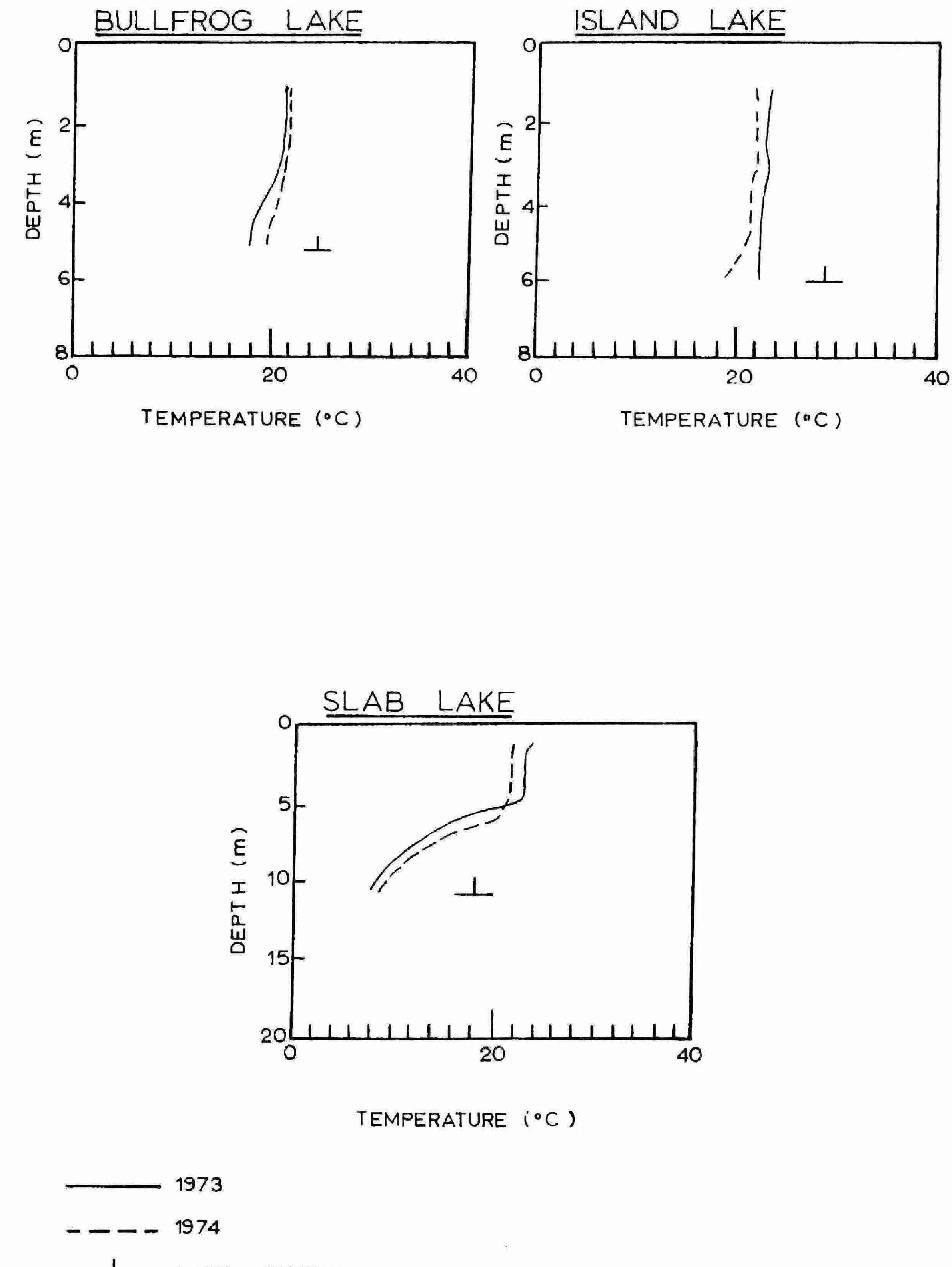
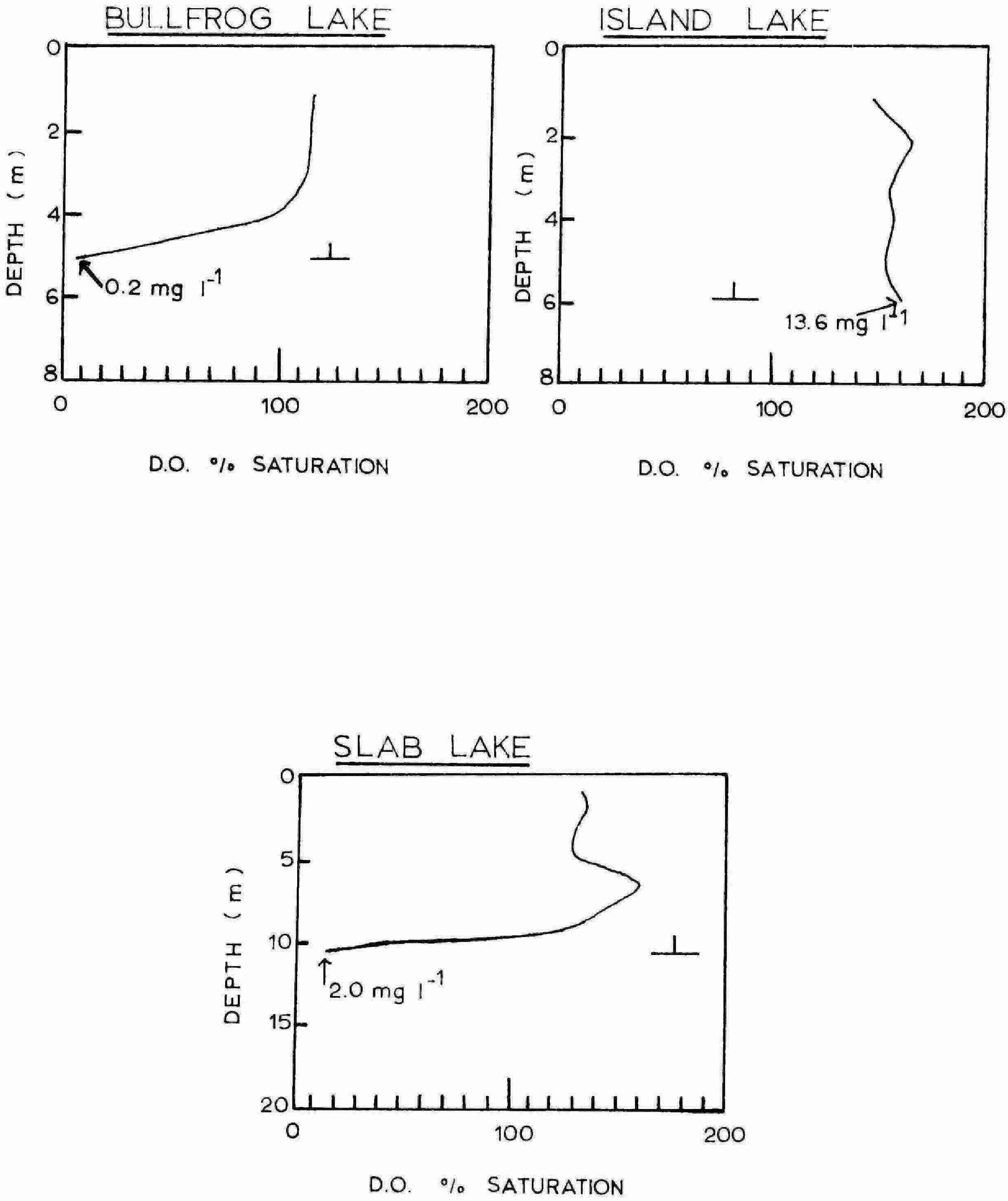


FIGURE 3.1.2.

DISSOLVED OXYGEN - DEPTH PROFILES

1973



⊥ LAKE BOTTOM

curve depicted in Figure 3.1.2 is a pulse of dissolved oxygen in the region of the thermocline. Distributions exhibiting such a metalimnetic (midwater) maximum are termed positive heterograde and are considered indicative of mesotrophic lakes by a number of authors (see Michalski, 1971). A critical level of dissolved oxygen was recorded in the bottom waters of Slab Lake during 1973 (2 mg l^{-1}); however, in 1974 an acceptable concentration (6 mg l^{-1}) was present.

3.2 WATER CHEMISTRY:

The results of chemical analyses are provided in Tables 3.2.1 and 3.2.2 for 1973 and 1974 respectively.

pH in the study lakes ranged from neutral to strongly basic (7.3, 9.1 and 7.9 for lakes Bullfrog, Island and Slab respectively).

The study lakes may be classed as soft water systems based on relatively low conductivity, alkalinity and generally low concentrations of the major ions. Slab Lake was found to be extremely dilute with a maximum recorded conductivity of 23.5 umho cm^{-1}. Conductivity - a measure of ionic strength, was significantly higher in Bullfrog and Island lakes (72 to 82 and 102 to 119.5 umho cm^{-1} respectively). Little difference in conductivity was noted between 1973 and 1974.

Based on 1973 data, concentrations of calcium were significantly higher in Island Lake (16 mg l^{-1}) than in Bullfrog and Slab Lakes (6 and 2 mg l^{-1} respectively) while the concentration of magnesium was highest in Bullfrog Lake (5 mg l^{-1}) and lowest in Slab Lake (<1 mg l^{-1}). The concentration of sodium was higher in Bullfrog Lake (6 mg.l^{-1}) than in Slab and Island Lakes (<1 to 1 mg l^{-1}) while the concentration of potassium was lower in Bullfrog Lake (1.3 mg l^{-1}) than in the other lakes (2.1 to 2.2 mg l^{-1}). Silica concentrations were highest in Island Lake (1.5 to 1.7 mg l^{-1}), lowest in Slab Lake (.10 to .15 mg l^{-1}) and intermediate in Bullfrog Lake (.25 to .6 mg l^{-1}).

The abundance of nutrients in a lake is extremely significant since these elements are of primary importance in the growth cycle of aquatic plants. Excessive quantities of water-borne nutrients may stimulate nuisance growths of algae and/or aquatic macrophytes. Table 3.2. 3 provides a summary of nutrient concentrations in the study lakes.

TABLE 3.2.3.

NUTRIENT CONCENTRATIONS, BULLFROG, ISLAND AND SLAB LAKES AUGUST 9, 1973 AND AUGUST 22, 1974.

Lake	Depth (m)	Inorganic Nitrogen ($NH_3 + NO_2 + NO_3$) 1973	1974	Total Phosphorus 1973	1974
Bullfrog	1	310	--	29	--
	5	23	21	36	20
Island	1	64	--	5	--
	6	53	31	7	7
Slab	1	51	--	8	--
	11	61	21	26	20

(Values in ug l^{-1})

TABLE 3.2.1.

RESULTS OF CHEMICAL ANALYSES AUGUST 9, 1973

LAKE	DEPTH	pH	ALK	COND.	Ca	Mg	Na	K	SILICA
Bullfrog	1 m. 5 m.	7.2 7.3	19 25	72. 82.	6 6	5 5	6 6	1.3 1.3	0.6 .25
Island	1 m. 6 m.	9.1 9.1	52 55	119.5 108.0	16 16	2 2	< 1 1	2.2 2.1	1.7 1.5
Slab	1 m. 11 m.	7.9 7.9	6 5	18.5 23.5	2 2	< 1 < 1	1 < 1	2.1 2.1	.15 .10

LAKE	DEPTH	NITROGEN NH_3	 KJEL.	 NO_3	 NO_2	PHOSPHORUS TOTAL	 SOLUBLE	 TOTAL	 SOLUBLE
Bullfrog	1 m. 5 m.	<.01 .01	.52 .59	.11 .003	.19 <.01	.029 .036	.008 .002	.10 1.4	<.05 <.05
Island	1 m. 6 m.	.04 .04	.31 .32	.004 .003	.02 <.01	<.005 .007	.004 .003	<.05 .05	<.05 <.05
Slab	1 m. 11 m.	.04 .05	.31 .46	.001 .001	<.01 <.01	.008 .026	.003 .010	<.05 .30	<.05 <.05

NOTE: All values expressed as mg l^{-1} except pH (pH units) and conductivity (umho cm^{-1})

TABLE 3.2.2

RESULTS OF CHEMICAL ANALYSES AUGUST 22, 1974

LAKE	DEPTH	NITROGEN NH_3	Kjel	NO_2	NO_3	TOTAL PHOSPHORUS	TOTAL IRON	CONDUCTIVITY
Bullfrog	5 m.	.01	.43	.001	<.01	.020	.65	73
Island	6 m.	.02	.41	.001	<.01	.007	.60	102
Slab	11 m.	<.01	.70	.001	<.01	.020	.45	21

NOTE: All values in mg l-' except conductivity (umho cm-')

Sawyer (1947) has suggested that excessive growths of algae may be expected to occur if total phosphorus and inorganic nitrogen concentrations exceed 20 and 300 ug l^{-1}, respectively, at the beginning of the growing season.

As shown in Table 3.2.1, with the exception of the surface waters of Bullfrog Lake during 1973, concentrations of inorganic nitrogen were far below Sawyer's suggested critical level. Total phosphorus concentrations exceeding Sawyer's limits (20 ug l^{-1} or greater) were recorded in Bullfrog and Slab Lakes during 1973 and 1974 while extremely low concentrations were detected in Island Lake (5 to 7 ug l^{-1}). The relatively high concentrations of total phosphorus observed in Bullfrog and Slab Lakes are not necessarily suggestive of artificial inputs; rather, they may reflect phosphorus contributions from the area's fertile soils. It is important to note that Sawyer's suggested limits are based on spring concentrations, while the values reported herein are midsummer concentrations. Since significant quantities of nutrients may be tied up in algal and aquatic macrophyte growth during the summer, springtime nutrient concentrations may be higher than those found during this study.

3.3 SECCHI DISC - CHLOROPHYLL A:

The results of Secchi disc - chlorophyll a sampling during 1973 are provided in Table 3.3.1. The values for 1974 are not included since sufficient data was not collected to permit a meaningful interpretation.

As indicated in Table 3.3.1, Bullfrog, Island and Slab Lakes had mean Secchi disc transparencies of 2.8, 5.3 and 4.9 metres respectively. Recent evidence suggests that lakes with Secchi disc readings less than 3 m are eutrophic (highly productive), lakes with readings exceeding 5 m are oligotrophic (unproductive), and lakes with Secchi disc transparencies between 3 and 5 m are mesotrophic (moderately productive). By these standards, Island and Slab Lakes (5.3 and 4.9 metres respectively) appear to be oligotrophic while Bullfrog Lake (2.8 m) appears in a eutrophic or late mesotrophic status.

Experience has indicated (see Robinson, 1974) that mean chlorophyll a concentrations between 0 and 3 ug l^{-1} are low - indicating low to moderate algal densities, concentrations between 3 and 6 ug l^{-1} are moderately high, and concentrations exceeding 6 ug l^{-1} are sufficiently high to adversely affect water quality for recreational purposes. Island and Slab Lakes exhibited low concentrations of chlorophyll a (1.6 and 1.9 ug l^{-1} respectively) considered typical of oligotrophic lakes. Bullfrog Lake exhibited a significantly higher chlorophyll a concentration (4.5 ug l^{-1}) indicative of the moderately high algal densities considered typical of mesotrophic lakes.

Ministry of the Environment staff have noted a near hyperbolic relationship between chlorophyll a concentrations and Secchi disc transparencies which can be used to bracket the trophic status of a lake. Figure 3.3.1 is a graph of this relationship with the values for the study lakes included. It is apparent from the graph that Island and Slab Lakes are oligotrophic - approaching the status of Lake Superior. Bullfrog Lake is located in the mesotrophic area of the curve, closely approaching mesotrophic Lake Ontario.

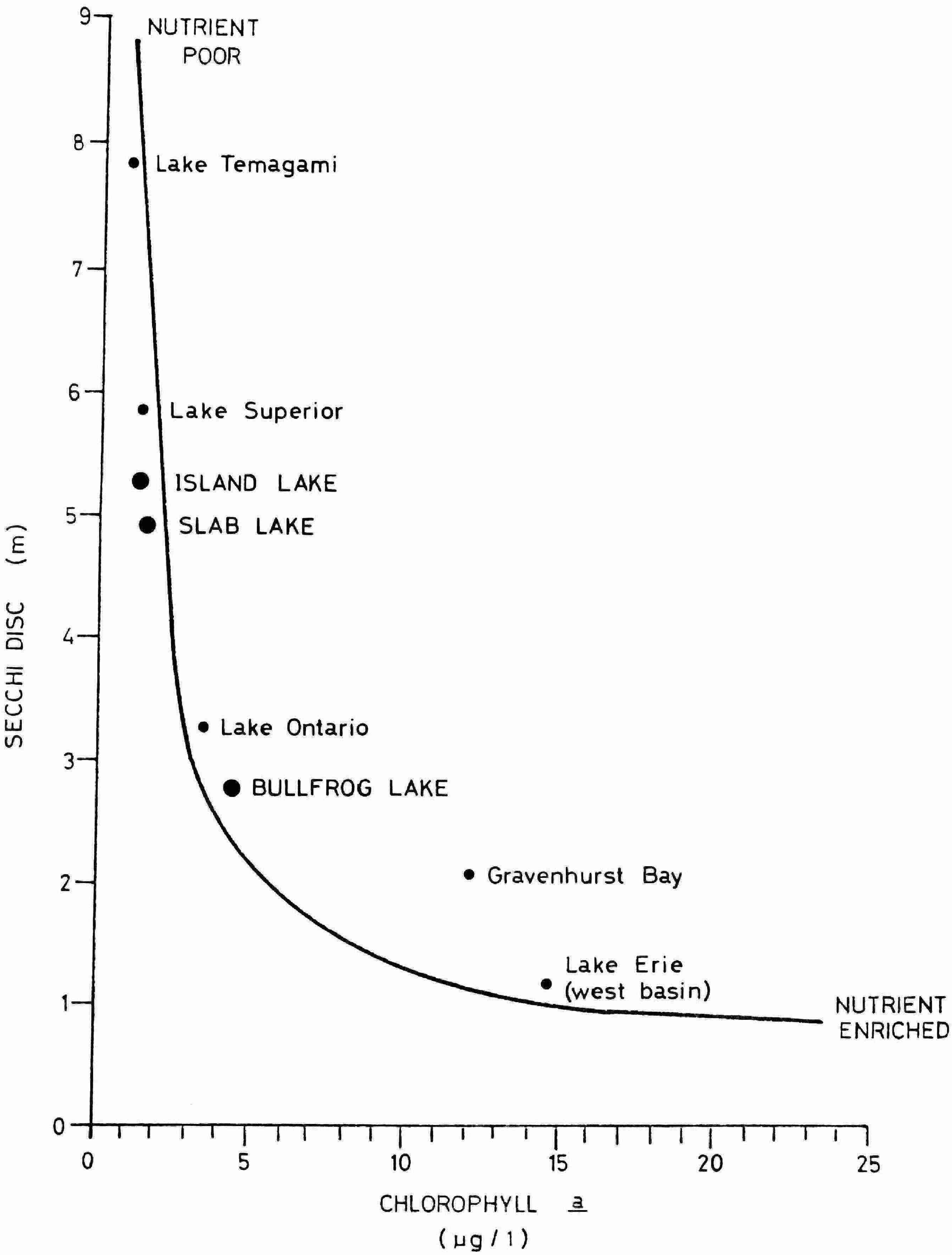
TABLE 3.3.1

RESULTS OF SECCHI DISC-CHLOROPHYLL A MONITORING, 1973

	Secchi Disc (m)	Chlorophyll *a* (μg/l)
BULLFROG LAKE		
June 6	2.7	2.8
13	3.3	2.8
20	2.4	5.2
July 4	2.6	4.3
11	3.0	3.0
25	3.4	4.5
Aug. 2	3.3	6.0
8	2.7	3.8
15	2.7	5.4
22	2.4	7.8
Mean	2.8	4.5
ISLAND LAKE		
June 6	8.4	0.6
13	7.2	<1.0
20	4.8	1.8
July 4	3.8	1.2
11	3.9	0.8
15	4.6	3.3
25	5.4	1.1
Aug. 2	4.6	3.8
8	4.5	1.9
15	5.7	0.5
22	5.1	1.9
Mean	5.3	1.6
SLAB LAKE		
June 6	4.2	1.4
13	4.2	2.5
20	4.5	3.5
July 4	3.6	-
11	4.2	1.4
25	6.4	0.0
Aug. 2	6.3	2.3
8	4.8	2.1
15	5.4	1.2
22	5.1	2.9
Mean	4.9	1.9

FIGURE 3.3.1.

THE RELATIONSHIP BETWEEN CHLOROPHYLL a & SECCHI DISC AS DETERMINED FROM ONTARIO LAKES



REFERENCES CITED

Michalski, M.F.P. 1971. Status of enrichment of Walkers Lake - Lake of Bays. Ontario Water Resources Commission.

Ministry of the Environment, 1972. Guidelines and criteria for water quality management in Ontario.

Robinson, G.W., 1974. Enrichment status of seventeen lakes in the northeastern region of Ontario. Ministry of the Environment.

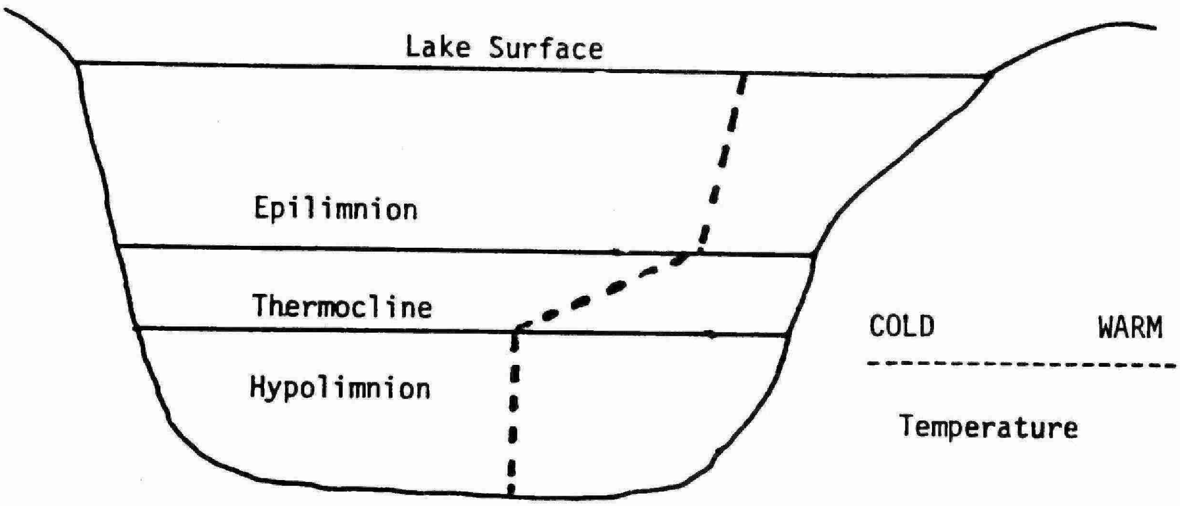
Sawyer, C.N., 1947. Fertilization of lakes by agriculture and urban drainage. N. England Water Works Assoc. 61: 109-127.

GLOSSARY

EPILIMNION - lakes which show thermal stratification have three distinct layers. The upper layer of water in which the temperature is relatively uniform is the epilimnion (see Figure A).

FIGURE A

Sketch of cross-section of theoretical lake during thermal stratification indicating water layers and temperature distribution.



EUPHOTIC ZONE - the intensity of light diminishes as it passes through water until at some depth there is insufficient light to carry on photosynthesis. This zone of significant light penetration is the euphotic zone.

EUTROPHIC - lakes are classified into three catagories on the basis of the biological activity - those with high biological activity and large nutrient concentrations are eutrophic. Characteristically eutrophic lakes are shallow, warm and highly turbid (see oligotrophic, mesotrophic and trophic status).

EUTROPHICATION - the process by which lakes become increasingly enriched in nutrients. It refers to the entire complex of changes which accompany nutrient enrichment including dense growth of algae and aquatic weeds.

HYPOLIMNION - the uniformly cold layer of water lying beneath the thermocline in thermally stratified lakes, (see Figure A).

MESOTROPHIC - those lakes with a moderate supply of nutrients and moderate biological activity, i.e. a trophic status lying between oligotrophic and eutrophic.

OLIGOTROPHIC - lakes with a meagre supply of nutrients and low biological activity. Characteristically oligotrophic lakes are deep, cold water, highly transparent bodies of water.

pH - a measure of acidity/alkalinity on a scale from 0-14 where 7.0 is neutral and 6.9-0 indicates increasing acidity and 7.1 to 14 increasing alkalinity.

strongly acid	acid	neutral	basic	strongly basic
0-3.9	4-6.9	7.0	7.1-10	10.1-14

natural water

THERMOCLINE - the mid layer of water in thermally stratified bodies of water in which the rate of change of temperature is a maximum.

TROPHIC STATUS - lakes are classified on the basis of the degree of nutrients enrichment and biological acitivity into three integrating types; oligotrophic, mesotrophic and eutrophic. Additions of nutrients to infertile lakes (oligotrophic) tned to make them mesotrophic and with continued enrichment they will become eutrophic.